PATENT ABSTRACTS OF JAPAN

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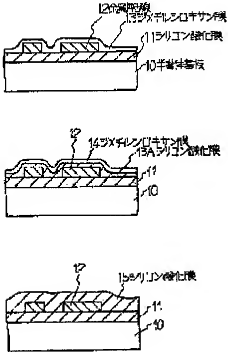
(54) MANUFACTURE OF SEMICONDUCTOR DEVICE

(57)Abstract:

PURPOSE: To form a silicon oxide film having a smooth surface and a minute film quality.

CONSTITUTION: On the surface of a semiconductor substrate 10 whereon a metallic wiring 12 is formed, a dimethylsiloxane film 13 is formed. Thereafter, this process and the process wherein the surface of the semiconductor substrate 10 is exposed to an oxidizing plasma are repeated alternately in a single equipment, and thereby, a silicon oxide film 15 is formed on the surface of the semiconductor substrate 10. Hereupon, the excitation frequency of the oxidizing plasma is forced to include the frequency components not higher than 1MHz, and thereby, the silicon oxide film 15 is made to have a compact film quality.



CLAIMS

[Claim(s)]

[Claim 1]. Are characterized by comprising the following. A manufacturing method of a semiconductor device including a process of repeating by turns a process of exposing to a process and oxidizing plasma which form a silicone series film in the whole surface with a CVD method, and changing a silicone series film into silicon oxide, within the same device, and forming silicon oxide of regular thickness.
A process of forming wiring on a semiconductor substrate.
This wiring.

[Claim 2]A manufacturing method of the semiconductor device according to claim 1 with which excitation frequency of said oxidizing plasma contains an ingredient of 1 MHz or less.
[Claim 3]A manufacturing method of the semiconductor device according to claim 1 which forms a silicone series film by decompression-ization containing at least one and a steam of halogenation organicity Silang, halogenation organic siloxane, or organic siloxane.
[Claim 4]A manufacturing method of the semiconductor device according to claim 1 which forms a silicone series film under a plasma atmosphere of gas containing organic siloxane and a steam.
[Claim 5]A manufacturing method of the semiconductor device according to claim 1 which forms a silicone series film under a plasma atmosphere of gas containing organic siloxane and oxygen.
[Claim 6]A manufacturing method of the semiconductor device according to claim 1 which exposes said semiconductor substrate to a plasma atmosphere of gas which contains nitrogen within the same device in advance of a process of forming said silicone series film.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application]Especially this invention relates to the formation method of silicon oxide about the manufacturing method of a semiconductor device.
[0002]
[Description of the Prior Art]In recent years, in the semiconductor device, the metallic wiring more than two-layer is used for the purpose of high integration and improvement in the speed. As an interlayer insulation film of these metallic wiring layers, although silicon oxide is generally used, in order to make easy the metallic wiring work process after a next process, the insulator layer which has the smooth surface is demanded with the minuteness making of metallic wiring, and high-aspect-ratio-izing.
[0003]Formation methods of the silicon oxide which has such the smooth surface conventionally include the method by spreading and plasma oxidation of silicone membrane, such as silicon shown in JP,1-130535,A, and Shiroki acid containing an organic group. This 1st conventional technology carries out spin spreading of the coating liquid for silicone series film formation on a semiconductor substrate, and forms a silicone series film at the temperature below 150 **. Then, the surface of a silicone series film is reformed to silicon oxide by introducing a semiconductor substrate into an inductive-coupling type plasma treatment apparatus, and exposing to oxygen plasma.
[0004]As the 2nd conventional technology. ** -- the -- Nine TINSU Conference One Solid state Debye Seth And As shown in MATERIARUZU (the 19 th Confereaceon Solid StateDevices andMaterials) P451, There is the method of forming from a tetramethylsilane and oxygen plasma. The siloxane membrane which has the mobility represented by hexamethyl disiloxane is formed by this 2nd conventional technology's installing a semiconductor substrate in a reaction chamber, and making the afterglow of a tetramethylsilane and oxygen plasma introduce and react to a semiconductor substrate surface.
[0005]Silang and oxygen plasma are introduced into the semiconductor substrate surface cooled by -110 ** as the same thing as the 2nd conventional technology, and the example of the 3rd conventional technology that forms the film of the silicon oxide stock which has mobility is shown in the collection (1991) P633 of the 38th applied-physics relation union lecture meeting drafts.
[0006]As the 4th conventional technology, it is 1991 VMIC. To the conference (1991VMIC Confevence) P435. A siloxane is compounded and the method of conveying to a semiconductor substrate surface and forming siloxane membrane is shown by by exciting pulse form plasma for a tetraethoxy run and a steam.
[0007]The process which furthermore introduces into a semiconductor substrate surface the silane gas by which plasma excitation was carried out as the 5th conventional technology, and makes the Silang radical (SiH_X) stick to a semiconductor surface, The method of repeating the process of introducing into a semiconductor substrate

surface the oxygen gas by which plasma excitation was carried out succeedingly, and oxidizing, within the same device, and forming silicon oxide, ZATOWEN tee first Conference One Solid State Debye Seth It is shown in and MATERIARUZU (the 21 st Conference on SolidState Devices and Materials) P49.

[0008]

[Problem(s) to be Solved by the Invention]When applying the insulator layer by the conventional technology mentioned above to the interlayer insulation film of a metallic wiring layer, following various difficulties are produced.

[0009]The case where the example of the 1st conventional technology is applied to the interlayer insulation film of a metallic wiring layer is explained using drawing 7. As shown in drawing 7 (a), the metallic wiring 12 which consists of aluminum etc. via the SHIRIKO oxide film 11 is formed on the semiconductor substrates 10, such as Si. After forming the silicone series film 20 on this next, the silicon oxide 21 by which refining was carried out by performing inductive-coupling type plasma treatment in that surface is formed. Next, as shown in drawing 7 (b), the photoresist film 22 which has an aperture is used as a mask, and the contact hole 23 is formed in a position by the dry etching method. Next, as shown in drawing 7 (c), oxygen plasma removes the photoresist film 22. At this time, the silicone series film 20 of the side of the contact hole 23 oxidizes by oxygen plasma, and deteriorates in the silicon oxide 24 of sparse membraneous quality. Since hygroscopicity was high, the silicon oxide 24 of this sparse membraneous quality absorbed the moisture in the atmosphere, and when it formed the upper metallic wiring layer, it had the problem of having made the upper metallic wiring generating an open circuit by the outgas of this absorbed moisture, or causing increase of contact resistance, succeedingly.

[0010]In the example of the 2nd conventional technology, in order [that it is **** with the low temperature of -40 ** in the reaction of a tetramethylsilane and oxygen] to divide, combination of a silicon oxide is not enough and membraneous quality serves as a non-dense. When applying this to the interlayer insulation film of a metallic wiring layer, film contraction takes place in heat treatment of a post process, for example, 400 **, and the formed siloxane tunic produces a crack. When this crack formed metallic wiring on it, it had the problem of causing an open circuit or a short circuit.

[0011]Also in the example of the 3rd and 4th conventional technologies, in order to perform film deposition at low temperature, there was a problem of producing a crack like the case of the 2nd conventional technology.

[0012]Furthermore, in the example of the 5th conventional technology, in order that there may be no mobility in the Silang radical, there is a fault that the smooth surface is not obtained. In order to use the afterglow of oxygen plasma for oxidation reaction, the ion energy of the gas molecule was small and there was a problem that the membraneous quality of the formed silicon oxide served as a non-dense, set like the heat process of eburnation like the example of the 2nd conventional technology, and produced a crack.

[0013]

[Means for Solving the Problem]A manufacturing method of a semiconductor device of this invention is provided with a process of repeating by turns a process of forming wiring on a semiconductor substrate, and a process of forming a silicone series film on this wiring and a process exposed to oxidizing plasma within the same device, and forming silicon oxide of regular thickness. And it has that excitation frequency of oxidizing plasma contains an ingredient of 1 MHz or less.

[0014]Under decompression which contains at least one and a steam of halogen organicity Silang, halogenation organic siloxane, or organic siloxane for said silicone series tunic, Or it forms, respectively in a plasma atmosphere of gas containing organic siloxane and a steam, or a plasma atmosphere of gas containing organic siloxane and oxygen.

[0015]

[Example]Next, this invention is explained with reference to drawings. Drawing 1 is drawing of longitudinal section of the main part of the silicon oxidation film forming device used in the manufacturing method of the

semiconductor device of this invention.

[0016]In the reaction chamber 1 provided with the exhaust pipe 5, the lower electrode 2 and the upper electrode 3 are countered and formed, and the semiconductor substrate 10 is installed on the lower electrode 2 by which temperature control was carried out. Oxidizing gases, such as organic-materials gas, such as organic siloxane and halogen organicity Silang, and oxygen, or a steam, are introduced in the reaction chamber 1 from the upper electrode 3 which has the aperture 4 through the piping 6 and 7, respectively, and are exhausted from the exhaust pipe 5. RF generator 8 and the low frequency power source 9 are connected to the upper electrode 3 and the lower electrode 2, respectively.

[0017]Next, about the 1st example of this invention, order is explained later on with reference to drawings. Drawing 2 (a) - (c) is a sectional view of the semiconductor chip for describing the 1st example of this invention.

[0018]As first shown in drawing 2 (a), after forming the silicon oxide 11 on the semiconductor substrate 10, the metallic wiring 12 which consists of aluminum etc. is formed. In next forming silicon oxide with a CVD method on this, the semiconductor substrate 10 is first installed on the lower electrode 2 of the device shown in drawing 1.

[0019]Next, 20sccm introduction of halogenation organicity Silang ($SiCl_2(CH_3)_2$), for example, the dichloro dimethylsilane, is carried out from the piping 6, and 50sccm introduction of the steam is carried out from the piping 7. The dimethylsiloxane film 14 is formed on the semiconductor substrate 10 by keeping [the inside of the reaction chamber 1] the temperature of 10mTorr and a lower electrode for a pressure at 50 **. Since a dimethylsiloxane film has surface tension as small as 20 dyn/cm, as shown in drawing 2 (a), it has the smooth surface. After forming the dimethylsiloxane film 13 about 100 nm thick, the piping 6 is closed, introduction of dichloro dimethylsilane is stopped, 60W is impressed by an RF generator and the electric power of 140W is impressed by a low frequency power source, respectively. 13.56 MHz is used as high frequency and 250 kHz is used as a low frequency wave.

[0020]By the plasma of the steam by which it is generated at this time, a dimethylsiloxane film oxidizes, and as shown in drawing 2 (b), it deteriorates in the silicon oxide 13A. So that 13.56 MHz may be used in order to raise oxygen radical density and to strengthen an oxidizing quality by [of 10Torr] generating plasma in high voltage comparatively, and the low frequency wave of 250 kHz may be mentioned later, It is for elaborating the silicon oxide 13A for ion energy by strength and ion bomber TOMENTO. By the plasma of this steam, the dimethylsiloxane film 13 of 100 nm of thickness oxidizes thoroughly, and turns into the precise silicon oxide 13A. Next, RF generator 8 and the low frequency power source 9 are intercepted, the piping 6 is opened, dichloro dimethylsilane is introduced again, and the dimethylsiloxane film 14 is again formed on the silicon oxide 13A at a thickness of about 100 nm. By exposing to steam plasma succeedingly, the dimethylsiloxane film 14 is deteriorated in precise silicon oxide.

[0021]Hereafter, by repeating oxidation by formation and steam plasma of a dimethylsiloxane film, as shown in drawing 2 (c), the precise silicon oxide 15 of predetermined thickness is obtained. Drawing 3 illustrates the temporal change of each parameter (a steam, dichloro dimethylsilane, electric power) of the silicon oxidation film formation mentioned above.

[0022]Film contraction of the silicon oxide which changed the frequency of the low frequency power source 9 impressed to the lower electrode 2, and formed it is shown in drawing 4. With film contraction, the difference of the thickness at the time of silicon oxidation film formation and the thickness after performing heat treatment for 30 minutes by a 900 ** nitrogen atmosphere is standardized by the thickness at the time of formation here. If film contraction generally exceeds 2%, hygroscopicity or moisture permeability increases, in the formation process of the metallic wiring of the upper layer of a next process, with the moisture from which it was desorbed, the upper metallic wiring will disconnect or short-circuit silicon oxide, and it will produce the serious problem for the manufacturing yield and reliability of a semiconductor device. According to drawing 4, the silicon oxide of the

precise membraneous quality of 2% or less of film contraction can be obtained by big ion energy by choosing 1 MHz or less as frequency of the power supply impressed to the lower electrode 2.
[0023]In the 1st example of the above, although a dimethylsiloxane film and plasma oxidation were repeated by turns for every 100-nm film formation and were performed, the thickness elaborated by ion bomber TOMENTO depends this on being limited to a depth of about 100 nm from the surface. For this reason, by the method of applying and carrying out plasma oxidation of the silicone series film shown by the 1st conventional technology, the neighborhood of the surface remains for deteriorating in silicon oxide, and a problem which was mentioned above is produced.
[0024]It divides 100 nm at a time, and in order to perform film formation and oxidation in the 1st example in the reaction-of-identity interior of a room as compared with the method of applying and carrying out plasma oxidation of the silicone series film, it has the advantage that process time can be shortened substantially. By repeating by turns the adsorption and oxidizing plasma of the Silang radical which were shown by the 3rd conventional technology, As compared with the method of forming silicon oxide, this example has the advantage that a precise oxide film is obtained by the oxidizing plasma containing the advantage and the low-frequency component of 1 MHz or less that surface smooth nature is obtained, by using a silicone series film.
[0025]In the 1st example, although dichloro dimethylsilane was used as halogenation organicity Silang, the effect that dichloro diethylsilane and a dichloro diphenylsilane are also the same is acquired. The same effect is acquired even if it uses the mixture of halogenation organicity Silang and halogenation organic siloxane, for example, JIKURO dimethylsilane, and dichloro tetramethyl disiloxane.
[0026]Next, the 2nd example of this invention is described with reference to drawings. Drawing 5 shows the temporal change of each parameter of the silicon oxidation film formation for describing the 2nd example of this invention.
[0027]In the 2nd example, the 1st example uses the plasma polymerization of organic siloxane and oxygen to having used the polymerization by hydrolysis of halogenation organicity Silang as a formation method of the silicone series film by a CVD method.
[0028]That is, in drawing 1, it is organic siloxane, for example, octamethylcyclotetrasiloxane, from the after-installation piping 6 on the lower electrode 2 about the semiconductor substrate 10. $[Si(CH_3)_2O]$ The electric power of 20W is made to impress to an upper electrode from a 13.56-MHz RF generator, and plasma is generated between an upper electrode and a lower electrode at the same time it introduces oxygen for $_4$ in the reaction chamber 1 10 sccm from 20sccm and the piping 7, respectively. The pressure in the reaction chamber 1 sets the temperature of 10Torr and a lower electrode as 200 **. The organic siloxane which has various molecular weights in this plasma, for example, poly dimethylsiloxane, is generated, and a film is formed on the semiconductor substrate 10.
[0029]Thus, after forming in a thickness of about 100 nm the silicone series film represented by poly dimethylsiloxane, Introduction of octamethylcyclotetrasiloxane is intercepted, an oxygen flow rate is set to 50sccm, and the electric power of 200W is simultaneously impressed to the lower electrode 2 for 60 seconds from a 250-kHz low frequency power source. As the 1st example was explained in full detail, a silicone series film deteriorates in precise silicon oxide by the plasma oxidation which has ion bomber TOMENTO by this low frequency wave. Hereafter, by repeating formation and plasma oxidation of a silicone series film by turns, like the 1st example, it has the smooth surface and only arbitrary thickness forms the silicon oxide of precise membraneous quality.
[0030]Although octamethylcyclotetrasiloxane was used as organic siloxane in the 2nd example, The same effect is acquired even if it uses methyl siloxanes, such as hexamethyl cyclotrisiloxane, decamethyl cyclopentasiloxane, a hexamethyl siloxane, or octamethyl trisiloxane. Furthermore, ethyl siloxanes and phenyl siloxanes may be used.

If halogen organicity Silang represented by such organic siloxanes at dichloro dimethylsilane is mixed, a polymerization will be promoted, and it becomes possible to raise the membrane formation speed of a silicone series film.

[0031]As the 3rd example, it replaces with the oxygen used in the 2nd example, and a steam is used. Since an acceleration decomposition reaction is added to a plasma polymerization, the membrane formation speed of a silicone series film increases further, and productivity can be improved.

[0032]As the 4th example, in the 1st example, it precedes forming a silicone series film and the semiconductor substrate 10 is exposed to the plasma of nitrogen gas. The temporal change of each parameter of silicon oxidation film formation is shown in drawing 6. It precedes forming a silicone series film, power supply power is set to 200W by setting N_2 flow to 100sccm, and it exposes for 10 seconds. Are nitriding [this processing / the surface of the silicon oxide 11 in drawing 2 (a)], and it hydrophobicity-izes. For this reason, the advantage that the wettability of a silicone series film (for example, dimethylsiloxane film 13) improves, and surface smoothness improves further is produced. Ammonia gas or those mixed gas besides nitrogen gas may be used.

[0033]

[Effect of the Invention]As explained above, in this invention, a silicone series film is formed on the semiconductor substrate in which wiring was formed, the process exposed to oxidizing plasma is repeated within the same device, and an ingredient of 1 MHz or less is included in the excitation power supply of oxidizing plasma, and silicon oxide is formed.

Therefore, it has the smooth surface and the silicon oxide of precise membraneous quality can be formed.

As a result, since it is lost that a crack occurs in silicon oxide in the heat treatment process of a next process, even if it forms the upper metallic wiring, it is lost that contact resistance increases, and it has the big effect that the manufacturing yield and reliability of a semiconductor device improve substantially.

[Translation done.]

TECHNICAL FIELD

[Industrial Application]Especially this invention relates to the formation method of silicon oxide about the manufacturing method of a semiconductor device.

[Translation done.]

PRIOR ART

[Description of the Prior Art]In recent years, in the semiconductor device, the metallic wiring more than two-layer is used for the purpose of high integration and improvement in the speed. As an interlayer insulation film of these metallic wiring layers, although silicon oxide is generally used, in order to make easy the metallic wiring work process after a next process, the insulator layer which has the smooth surface is demanded with the minuteness making of metallic wiring, and high-aspect-ratio-izing.
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EFFECT OF THE INVENTION

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TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention]When applying the insulator layer by the conventional technology mentioned above to the interlayer insulation film of a metallic wiring layer, following various difficulties are produced.
[0009]The case where the example of the 1st conventional technology is applied to the interlayer insulation film of a metallic wiring layer is explained using drawing 7. As shown in drawing 7 (a), the metallic wiring 12 which consists of aluminum etc. via the SHIRIKO oxide film 11 is formed on the semiconductor substrates 10, such as Si. After forming the silicone series film 20 on this next, the silicon oxide 21 by which refining was carried out by performing inductive-coupling type plasma treatment in that surface is formed. Next, as shown in drawing 7 (b), the photoresist film 22 which has an aperture is used as a mask, and the contact hole 23 is formed in a position by the dry etching method. Next, as shown in drawing 7 (c), oxygen plasma removes the photoresist film 22. At this time, the silicone series film 20 of the side of the contact hole 23 oxidizes by oxygen plasma, and deteriorates in the silicon oxide 24 of sparse membraneous quality. Since hygroscopicity was high, the silicon oxide 24 of this sparse membraneous quality absorbed the moisture in the atmosphere, and when it formed the upper metallic wiring layer, it had the problem of having made the upper metallic wiring generating an open circuit by the outgas of this absorbed moisture, or causing increase of contact resistance, succeedingly.
[0010]In the example of the 2nd conventional technology, in order [that it is **** with the low temperature of -40 ** in the reaction of a tetramethylsilane and oxygen] to divide, combination of a silicon oxide is not enough and membraneous quality serves as a non-dense. When applying this to the interlayer insulation film of a metallic wiring layer, film contraction takes place in heat treatment of a post process, for example, 400 **, and the formed siloxane tunic produces a crack. When this crack formed metallic wiring on it, it had the problem of causing an open circuit or a short circuit.
[0011]Also in the example of the 3rd and 4th conventional technologies, in order to perform film deposition at low temperature, there was a problem of producing a crack like the case of the 2nd conventional technology.
[0012]Furthermore, in the example of the 5th conventional technology, in order that there may be no mobility in the Silang radical, there is a fault that the smooth surface is not obtained. In order to use the afterglow of oxygen plasma for oxidation reaction, the ion energy of the gas molecule was small and there was a problem that the membraneous quality of the formed silicon oxide served as a non-dense, set like the heat process of eburnation like the example of the 2nd conventional technology, and produced a crack.

[Translation done.]

MEANS

[Means for Solving the Problem]A manufacturing method of a semiconductor device of this invention is provided with a process of repeating by turns a process of forming wiring on a semiconductor substrate, and a process of forming a silicone series film on this wiring and a process exposed to oxidizing plasma within the same device, and forming silicon oxide of regular thickness. And it has that excitation frequency of oxidizing plasma contains an ingredient of 1 MHz or less.
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EXAMPLE

[Example]Next, this invention is explained with reference to drawings. Drawing 1 is drawing of longitudinal section of the main part of the silicon oxidation film forming device used in the manufacturing method of the semiconductor device of this invention.
[0016]In the reaction chamber 1 provided with the exhaust pipe 5, the lower electrode 2 and the upper electrode 3 are countered and formed, and the semiconductor substrate 10 is installed on the lower electrode 2 by which temperature control was carried out. Oxidizing gases, such as organic-materials gas, such as organic siloxane and halogen organicity Silang, and oxygen, or a steam, are introduced in the reaction chamber 1 from the upper electrode 3 which has the aperture 4 through the piping 6 and 7, respectively, and are exhausted from the exhaust pipe 5. RF generator 8 and the low frequency power source 9 are connected to the upper electrode 3 and the lower electrode 2, respectively.
[0017]Next, about the 1st example of this invention, order is explained later on with reference to drawings. Drawing 2 (a) - (c) is a sectional view of the semiconductor chip for describing the 1st example of this invention.
[0018]As first shown in drawing 2 (a), after forming the silicon oxide 11 on the semiconductor substrate 10, the metallic wiring 12 which consists of aluminum etc. is formed. In next forming silicon oxide with a CVD method on this, the semiconductor substrate 10 is first installed on the lower electrode 2 of the device shown in drawing 1.
[0019]Next, 20sccm introduction of halogenation organicity Silang ($SiCl_2(CH_3)_2$), for example, the dichloro dimethylsilane, is carried out from the piping 6, and 50sccm introduction of the steam is carried out from the piping 7. The dimethylsiloxane film 14 is formed on the semiconductor substrate 10 by keeping [the inside of the reaction chamber 1] the temperature of 10mTorr and a lower electrode for a pressure at 50 **. Since a dimethylsiloxane film has surface tension as small as 20 dyn/cm, as shown in drawing 2 (a), it has the smooth surface. After forming the dimethylsiloxane film 13 about 100 nm thick, the piping 6 is closed, introduction of dichloro dimethylsilane is stopped, 60W is impressed by an RF generator and the electric power of 140W is impressed by a low frequency power source, respectively. 13.56 MHz is used as high frequency and 250 kHz is used as a low frequency wave.
[0020]By the plasma of the steam by which it is generated at this time, a dimethylsiloxane film oxidizes, and as shown in drawing 2 (b), it deteriorates in the silicon oxide 13A. So that 13.56 MHz may be used in order to raise oxygen radical density and to strengthen an oxidizing quality by [of 10Torr] generating plasma in high voltage comparatively, and the low frequency wave of 250 kHz may be mentioned later, It is for elaborating the silicon oxide 13A for ion energy by strength and ion bomber TOMENTO. By the plasma of this steam, the dimethylsiloxane film 13 of 100 nm of thickness oxidizes thoroughly, and turns into the precise silicon oxide 13A. Next, RF generator 8 and the low frequency power source 9 are intercepted, the piping 6 is opened, dichloro dimethylsilane is introduced again, and the dimethylsiloxane film 14 is again formed on the silicon oxide 13A at a thickness of about 100 nm. By exposing to steam plasma succeedingly, the dimethylsiloxane film 14 is

deteriorated in precise silicon oxide.

[0021]Hereafter, by repeating oxidation by formation and steam plasma of a dimethylsiloxane film, as shown in drawing 2 (c), the precise silicon oxide 15 of predetermined thickness is obtained. Drawing 3 illustrates the temporal change of each parameter (a steam, dichloro dimethylsilane, electric power) of the silicon oxidation film formation mentioned above.

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[0023]In the 1st example of the above, although a dimethylsiloxane film and plasma oxidation were repeated by turns for every 100-nm film formation and were performed, the thickness elaborated by ion bomber TOMENTO depends this on being limited to a depth of about 100 nm from the surface. For this reason, by the method of applying and carrying out plasma oxidation of the silicone series film shown by the 1st conventional technology, the neighborhood of the surface remains for deteriorating in silicon oxide, and a problem which was mentioned above is produced.

[0024]It divides 100 nm at a time, and in order to perform film formation and oxidation in the 1st example in the reaction-of-identity interior of a room as compared with the method of applying and carrying out plasma oxidation of the silicone series film, it has the advantage that process time can be shortened substantially. By repeating by turns the adsorption and oxidizing plasma of the Silang radical which were shown by the 3rd conventional technology, As compared with the method of forming silicon oxide, this example has the advantage that a precise oxide film is obtained by the oxidizing plasma containing the advantage and the low-frequency component of 1 MHz or less that surface smooth nature is obtained, by using a silicone series film.

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[0028]That is, in drawing 1, it is organic siloxane, for example, octamethylcyclotetrasiloxane, from the after-installation piping 6 on the lower electrode 2 about the semiconductor substrate 10. [$Si(CH_3)_2O$] The electric power of 20W is made to impress to an upper electrode from a 13.56-MHz RF generator, and plasma is generated between an upper electrode and a lower electrode at the same time it introduces oxygen for $_4$ in the reaction chamber 1 10 sccm from 20sccm and the piping 7, respectively. The pressure in the reaction chamber 1 sets the temperature of 10Torr and a lower electrode as 200 **. The organic siloxane which has various molecular

weights in this plasma, for example, poly dimethylsiloxane, is generated, and a film is formed on the semiconductor substrate 10.

[0029]Thus, after forming in a thickness of about 100 nm the silicone series film represented by poly dimethylsiloxane, Introduction of octamethylcyclotetrasiloxane is intercepted, an oxygen flow rate is set to 50sccm, and the electric power of 200W is simultaneously impressed to the lower electrode 2 for 60 seconds from a 250-kHz low frequency power source. As the 1st example was explained in full detail, a silicone series film deteriorates in precise silicon oxide by the plasma oxidation which has ion bomber TOMENTO by this low frequency wave. Hereafter, by repeating formation and plasma oxidation of a silicone series film by turns, like the 1st example, it has the smooth surface and only arbitrary thickness forms the silicon oxide of precise membraneous quality.

[0030]Although octamethylcyclotetrasiloxane was used as organic siloxane in the 2nd example, The same effect is acquired even if it uses methyl siloxanes, such as hexamethyl cyclotrisiloxane, decamethyl cyclopentasiloxane, a hexamethyl siloxane, or octamethyl trisiloxane. Furthermore, ethyl siloxanes and phenyl siloxanes may be used. If halogen organicity Silang represented by such organic siloxanes at dichloro dimethylsilane is mixed, a polymerization will be promoted, and it becomes possible to raise the membrane formation speed of a silicone series film.

[0031]As the 3rd example, it replaces with the oxygen used in the 2nd example, and a steam is used. Since an acceleration decomposition reaction is added to a plasma polymerization, the membrane formation speed of a silicone series film increases further, and productivity can be improved.

[0032]As the 4th example, in the 1st example, it precedes forming a silicone series film and the semiconductor substrate 10 is exposed to the plasma of nitrogen gas. The temporal change of each parameter of silicon oxidation film formation is shown in drawing 6. It precedes forming a silicone series film, power supply power is set to 200W by setting N_2 flow to 100sccm, and it exposes for 10 seconds. Are nitriding [this processing / the surface of the silicon oxide 11 in drawing 2 (a)], and it hydrophobicity-izes. For this reason, the advantage that the wettability of a silicone series film (for example, dimethylsiloxane film 13) improves, and surface smoothness improves further is produced. Ammonia gas or those mixed gas besides nitrogen gas may be used.

[Translation done.]

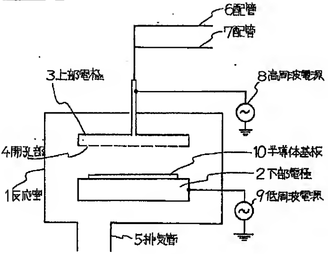
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1]The lineblock diagram of the main part of the device used in the example of this invention.
[Drawing 2]The sectional view of the semiconductor chip for describing the 1st example of this invention.
[Drawing 3]The figure showing the change to the time of each parameter for describing the 1st example of this invention.
[Drawing 4]The figure showing the relation between contraction of silicon oxide, and the frequency of a low frequency wave.
[Drawing 5]The figure showing the change to the time of each parameter for describing the 2nd example of this invention.
[Drawing 6]The figure showing the change to the time of each parameter for describing the 3rd example of this invention.
[Drawing 7]The sectional view of the semiconductor chip for explaining an example of the conventional semiconductor device.
[Description of Notations]
1 Reaction chamber
2 Lower electrode
3 Upper electrode
4 Aperture
5 Exhaust pipe
6 and 7 Piping
8 RF generator
9 Low frequency power source
10 Semiconductor substrate
11 Silicon oxide
12 Metallic wiring
13 and 14 Dimethylsiloxane film
13A, 15 silicon oxide
20 Silicone series film
21 Silicon oxide
22 Photoresist film
23 Contact hole
24 Silicon oxide of sparse membraneous quality

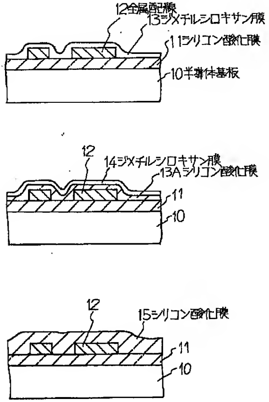
[Translation done.]

DRAWINGS

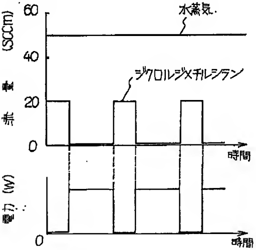
[Drawing 1]



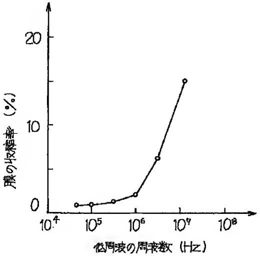
[Drawing 2]



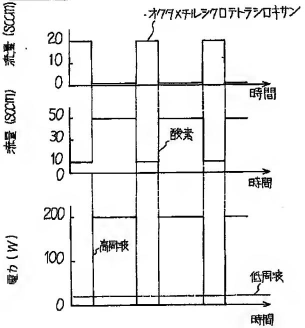
[Drawing 3]



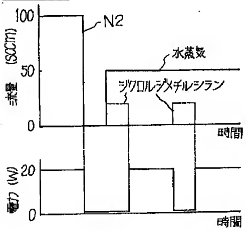
[Drawing 4]



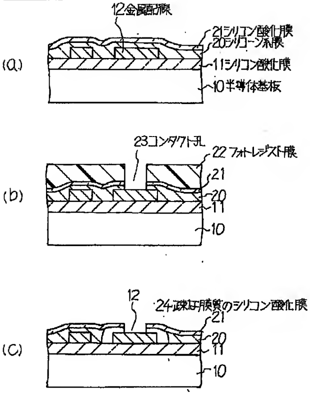
[Drawing 5]



[Drawing 6]



[Drawing 7]



[Translation done.]

PATENT ABSTRACTS OF JAPAN

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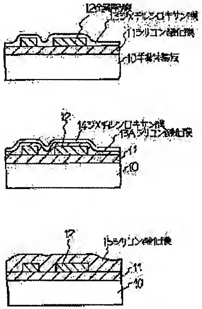
DEN YASUHIDE

(54) MANUFACTURE OF SEMICONDUCTOR DEVICE

(57)Abstract:
PURPOSE: To form a silicon oxide film having a smooth surface and a minute film quality.
CONSTITUTION: On the surface of a semiconductor substrate 10 whereon a metallic wiring 12 is formed, a dimethylsiloxane film 13 is formed. Thereafter, this process and the process wherein the surface of the semiconductor substrate 10 is exposed to an oxidizing plasma are repeated alternately in a single equipment, and thereby, a silicon oxide film 15 is formed on the surface of the semiconductor substrate 10. Hereupon, the excitation frequency of the oxidizing plasma is forced to include the frequency components not higher than 1MHz, and thereby, the silicon oxide film 15 is made to have a compact film quality.



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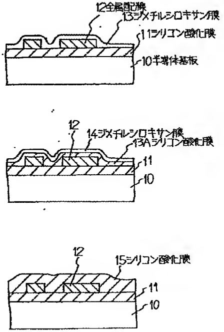
(54)【発明の名称】　半導体装置の製造方法

(57)【要約】

【目的】平滑な表面を有し、且つ緻密な膜質のシリコン酸化膜を形成する。

【構成】金属配線１２が形成された半導体基板１０の表面にジメチルシロキサン膜１３を形成したのち酸化性プラズマにさらす工程とを同一装置内で交互に繰り返して、半導体基板表面にシリコン酸化膜１５を形成する。ここで、酸化性プラズマの励起周波数に１ＭＨｚ以下の成分を含ませることにより、シリコン酸化膜１５は緻密な膜質となる。



【特許請求の範囲】

【請求項１】　半導体基板上に配線を形成する工程と、該配線を含む全面にＣＶＤ法によりシリコーン系膜を形成する工程と酸化性プラズマにさらしシリコーン系膜をシリコン酸化膜に変える工程とを同一装置内で交互に繰り返し規定の厚さのシリコン酸化膜を形成する工程とを含むことを特徴とする半導体装置の製造方法。

【請求項２】　前記酸化性プラズマの励起周波数が１ＭＨｚ以下の成分を含む請求項１記載の半導体装置の製造方法。

【請求項３】　ハロゲン化有機シランまたはハロゲン化有機シロキサンまたは有機シロキサンの少くとも１つと水蒸気とを含む減圧化でシリコーン系膜を形成する請求項１記載の半導体装置の製造方法。

【請求項４】　有機シロキサンと水蒸気とを含むガスのプラズマ雰囲気下でシリコーン系膜を形成する請求項１記載の半導体装置の製造方法。

【請求項５】　有機シロキサンと酸素を含むガスのプラズマ雰囲気下でシリコーン系膜を形成する請求項１記載の半導体装置の製造方法。

【請求項６】　前記シリコーン系膜を形成する工程に先立って、同一装置内で窒素を含むガスのプラズマ雰囲気に前記半導体基板をさらす請求項１記載の半導体装置の製造方法。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は半導体装置の製造方法に関し、特にシリコン酸化膜の形成方法に関する。

【０００２】

【従来の技術】近年、半導体装置においては高集積化、高速化を目的として２層以上の金属配線が用いられている。これらの金属配線層の層間絶縁膜としては、一般にシリコン酸化膜が用いられるが、金属配線の微細化，高アスペクト比化に伴って、次工程以降の金属配線加工工程を容易にするために平滑な表面を有する絶縁膜が要求されている。

【０００３】従来、このような平滑な表面を有するシリコン酸化膜の形成方法として、特開平１－１３０５３５号公報に示されているシリコンと有機基を含むシロキ酸等のシリコーン膜の塗布およびプラズマ酸化による方法がある。この第１の従来技術は、シリコーン系膜形成用塗布液を半導体基板上にスピン塗布し、１５０℃未満の温度でシリコーン系膜を形成する。引き続いて、誘導結合型プラズマ処理装置に半導体基板を導入し、酸素プラズマにさらすことにより、シリコーン系膜の表面をシリコン酸化膜に改質するものである。

【０００４】第２の従来技術としてはザ　ナインティーンス　コンファレンス　オン　ソリッド　ステート　デバイセス　アンド　マテリアルズ（ｔｈｅ　１９ｔｈ　Ｃｏｎｆｅｒｅａｃｅ　ｏｎ　Ｓｏｌｉｄ　Ｓｔａｔｅ　Ｄｅｖｉｃｅｓ　ａｎｄＭａｔｅｒｉａｌｓ）Ｐ４５１に示されているように、テトラメチルシランと酸素プラズマとから形成する方法がある。この第２の従来技術は、半導体基板を反応室に設置し、半導体基板表面にテトラメチルシランと酸素プラズマのアフターグローを導入して反応させることにより、ヘキサメチルジシロキサンに代表される流動性を有するシロキサン膜が形成される。

【０００５】第２の従来技術と同様のものとして、シランと酸素プラズマを－１１０℃に冷却された半導体基板表面に導入して、流動性を有するシリコン酸化物系の膜を形成する第３の従来技術の例が第３８回応用物理学関係連合講演会予稿集（１９９１年）Ｐ６３３に示されている。

【０００６】また第４の従来技術として、１９９１年ＶＭＩＣ　コンファレンス（１９９１ＶＭＩＣ　Ｃｏｎｆｅｖｅｎｃｅ）Ｐ４３５に、テトラエトキシシランと水蒸気をパルス状プラズマを励起させることによりシロキサンを合成し、半導体基板表面に輸送してシロキサン膜を形成する方法が示されている。

【０００７】更に第５の従来技術として、プラズマ励起されたシランガスを半導体基板表面に導入し、シランラジカル（ＳｉＨx）を半導体表面に吸着させる工程と、引き続いてプラズマ励起された酸素ガスを半導体基板表面に導入して酸化する工程とを同一装置内で繰り返してシリコン酸化膜を形成する方法が、ザ　トウェンティファースト　コンファレンス　オン　ソリッド　ステート　デバイセス　アンドマテリアルズ（ｔｈｅ　２１ｓｔ　Ｃｏｎｆｅｒｅｎｃｅ　ｏｎ　ＳｏｌｉｄＳｔａｔｅ　Ｄｅｖｉｃｅｓ　ａｎｄ　Ｍａｔｅｒｉａｌｓ）Ｐ４９に示されている。

【０００８】

【発明が解決しようとする課題】上述した従来技術による絶縁膜を金属配線層の層間絶縁膜に適用する場合、次のような種々の困難を生ずる。

【０００９】第１の従来技術の例を金属配線層の層間絶縁膜に適用した場合について図７を用いて説明する。図７（ａ）に示すように、Ｓｉ等の半導体基板１０上にシリコ酸化膜１１を介してＡｌ等からなる金属配線１２を形成する。次でこの上にシリコーン系膜２０を形成したのちその表面を誘導結合型プラズマ処理を行ない、改質されたシリコン酸化膜２１を形成する。次に図７（ｂ）に示すように、所定の位置に開孔部を有するフォトレジスト膜２２をマスクとし、ドライエッチング法によってコンタクト孔２３を形成する。次で図７（ｃ）に示すように、フォトレジスト膜２２を酸素プラズマによって除去する。この時コンタクト孔２３の側面のシリコーン系膜２０が酸素プラズマによって酸化され、疎な膜質のシリコン酸化膜２４に変質する。この疎な膜質のシリコン酸化膜２４は吸湿性が高い為、大気中の水分を吸収し、

引き続いて、上層の金属配線層を形成する際、吸収されたこの水分のアウトガスによって上層の金属配線に断線を発生させたり、コンタクト抵抗の増大を招くという問題があった。

【0010】また、第2の従来技術の例においては、テトラメチルシランと酸素との反応が－４０℃という低温で行なわる為、シリコン酸化物の結合が十分でなく、膜質が疎となる。これを金属配線層の層間絶縁膜に適用する場合、形成されたシロキサン被膜は後工程の熱処理、例えば４００℃において膜収縮が起りクラックを生じる。このクラックはその上に金属配線を形成する際、断線或は短絡を引き起こすという問題があった。

【００１１】第３および第４の従来技術の例においても、低温で膜堆積を行なう為、第２の従来技術の場合と同様にクラックを生じるという問題があった。

【００１２】さらに第５の従来技術の例においては、シランラジカルに流動性が無い為、平滑な表面が得られないという欠点がある。また酸化反応に酸素プラズマのアフターグローを用いるため、ガス分子のイオンエネルギーが小さく、形成されたシリコン酸化膜の膜質が疎となり、第２の従来技術の例と同様に、緻密化の熱工程においてクラックを生じるという問題があった。

【００１３】

【課題を解決するための手段】本発明の半導体装置の製造方法は、半導体基板上に配線を形成する工程と、この配線上にシリコーン系膜を形成する工程と酸化性プラズマにさらす工程とを同一装置内で交互に繰り返して規定の厚さのシリコン酸化膜を形成する工程を備えている。そして、酸化性プラズマの励起周波数が１ＭＨｚ以下の成分を含むことを備えている。

【００１４】また前記シリコーン系被膜を、ハロゲン有機シランまたはハロゲン化有機シロキサンまたは有機シロキサンの少くとも１つと水蒸気を含む減圧下、または有機シロキサンと水蒸気を含むガスのプラズマ雰囲気中、または有機シロキサンと酸素を含むガスのプラズマ雰囲気中でそれぞれ形成するものである。

【００１５】

【実施例】次に本発明について、図面を参照して説明する。図１は本発明の半導体装置の製造方法において用いられるシリコン酸化膜形成装置の主要部分の縦断面図である。

【００１６】排気管５を備えた反応室１内には下部電極２と上部電極３が対向して設けられ、半導体基板１０は、温度制御された下部電極２の上に設置される。有機シロキサン，ハロゲン有機シラン等の有機材料ガス及び酸素または水蒸気等の酸化性ガスはそれぞれ配管６，７を通って開孔部４を有する上部電極３から反応室１内に導入され、排気管５より排気される。上部電極３および下部電極２にはそれぞれ高周波電源８および低周波電源９が接続されている。

【００１７】次に本発明の第１の実施例について、図面を参照して順を追って説明する。図２（ａ）～（ｃ）は本発明の第１の実施例を説明するための半導体チップの断面図である。

【００１８】まず図２（ａ）に示すように、半導体基板１０の上にシリコン酸化膜１１を形成したのちＡｌ等からなる金属配線１２を形成する。次でこの上にＣＶＤ法によりシリコン酸化膜を形成するに当り、まず半導体基板１０を図１に示した装置の下部電極２上に設置する。

【００１９】次に、配管６からハロゲン化有機シラン、例えばジクロルジメチルシラン（$SiCl_2(CH_3)_2$）を２０ｓｃｃｍ導入し、配管７から水蒸気を５０ｓｃｃｍ導入する。反応室１内を圧力を１０ｍＴｏｒｒ，下部電極の温度を５０℃に保つことにより、半導体基板１０上にジメチルシロキサン膜１４を形成する。ジメチルシロキサン膜は表面張力が２０ｄｙｎ／ｃｍと小さい為、図２（ａ）に示したように、平滑な表面を有する。厚さ約１００ｎｍのジメチルシロキサン膜１３を形成した後、配管６を閉じてジクロルジメチルシランの導入を止め、高周波電源で６０Ｗ，低周波電源で１４０Ｗの電力をそれぞれ印加する。高周波としては例えば１３．５６ＭＨｚ、低周波としては２５０ＫＨｚを用いる。

【００２０】この時発生する水蒸気のプラズマによってジメチルシロキサン膜は酸化されて、図２（ｂ）に示すように、シリコン酸化膜１３Ａに変質する。１３．５６ＭＨｚを用いるのは１０Ｔｏｒｒという比較的高圧でプラズマを発生させることにより酸素ラジカル密度を高めて酸化性を強める為であり、２５０ＫＨｚという低周波は、後述するように、イオンエネルギーを強め、イオンボンバートメントによってシリコン酸化膜１３Ａを緻密化する為である。この水蒸気のプラズマによって膜厚１００ｎｍのジメチルシロキサン膜１３は完全に酸化され、緻密なシリコン酸化膜１３Ａとなる。次に、高周波電源８及び低周波電源９をしゃ断し、配管６を開けて再びジクロルジメチルシランを導入しシリコン酸化膜１３Ａの上に再びジメチルシロキサン膜１４を約１００ｎｍの厚さに形成する。引き続いて水蒸気プラズマにさらすことにより、ジメチルシロキサン膜１４を緻密なシリコン酸化膜に変質する。

【００２１】以下、ジメチルシロキサン膜の形成と水蒸気プラズマによる酸化を繰り返すことによって、図２（ｃ）に示すように、所定の膜厚の緻密なシリコン酸化膜１５を得る。図３は上述したシリコン酸化膜形成の各パラメータ（水蒸気，ジクロルジメチルシラン，電力）の時間変化を図示したものである。

【００２２】下部電極２に印加する低周波電源９の周波数を変化させて形成したシリコン酸化膜の膜収縮率を図４に示す。ここで膜収縮率とは、シリコン酸化膜形成時の膜厚と、９００℃窒素雰囲気で３０分間の熱処理を行なった後の膜厚の差を形成時の膜厚で規格化したもので

ある。一般に膜収縮率が２％を超えるとシリコン酸化膜は吸湿性あるいは透湿性が高まり、次工程の上層の金属配線の形成工程において、脱離した水分によって上層の金属配線が断線或は短絡し半導体装置の製造歩留り及び信頼性に重大な問題を生じる。図４によれば、下部電極２に印加する電源の周波数として１ＭＨｚ以下を選択することにより、大きなイオンエネルギーによって、膜収縮率２％以下の緻密な膜質のシリコン酸化膜を得ることができる。

【００２３】なお、上記第１の実施例においては、ジメチルシロキサン膜とプラズマ酸化を１００ｎｍの膜形成毎に交互に繰り返して行なったが、これはイオンボンバートメントによって緻密化される膜厚が、表面から１０ｎｍ程度の深さに限定されることによる。この為、第１の従来技術で示したシリコーン系膜を塗布しプラズマ酸化する方法では、表面近傍がシリコン酸化膜に変質するにとどまり、前述したような問題を生じる。

【００２４】また、１００ｎｍずつ分けて、シリコーン系膜を塗布し、プラズマ酸化する方法に比較して本第１の実施例では、同一反応室内で膜形成と酸化を行なう為、プロセス時間を大幅に短縮できるという利点を有する。また、第３の従来技術で示したシランラジカルの吸着と酸化性プラズマを交互に繰り返すことにより、シリコン酸化膜を形成する方法に比較して本実施例はシリコーン系膜を用いることにより表面の平滑性が得られるという利点および１ＭＨｚ以下の低周波成分を含む酸化性プラズマによって緻密な酸化膜が得られるという利点を有している。

【００２５】なお、第１の実施例においては、ハロゲン化有機シランとしてジクロルジメチルシランを用いたが、ジクロルジエチルシランやジクロルジフェニルシラン等でも同様の効果が得られる。さらに、ハロゲン化有機シランとハロゲン化有機シロキサンの混合物、例えばジクロジメチルシランとジクロルテトラメチルジシロキサンを用いても同様の効果が得られる。

【００２６】次に本発明の第２の実施例について、図面を参照して説明する。図５は本発明第２の実施例を説明するためのシリコン酸化膜形成の各パラメータの時間変化を示したものである。

【００２７】第１の実施例がＣＶＤ法によるシリコーン系膜の形成方法としてハロゲン化有機シランの加水分解による重合を用いたのに対し、本第２の実施例においては、有機シロキサンと酸素のプラズマ重合を用いる。

【００２８】即ち、図１において半導体基板１０を下部電極２上に設置後配管６から有機シロキサン、例えばオクタメチルシクロテトラシロキサン〔$Si(CH_3)_2O$〕$_4$ を２０ｓｃｃｍ、配管７から酸素を１０ｓｃｃｍそれぞれ反応室１内に導入すると同時に、上部電極に１３．５６ＭＨｚの高周波電源から２０Ｗの電力を印加させ上部電極と下部電極間にプラズマを発生させる。反応室１内の圧力は１０Ｔｏｒｒ，下部電極の温度は２００℃に設定する。このプラズマ内において種々の分子量を有する有機シロキサン、例えばポリジメチルシロキサンが生成され、半導体基板１０上に膜が形成される。

【００２９】このようにしてポリジメチルシロキサンに代表されるシリコーン系膜を約１００ｎｍの厚さに形成したのち、オクタメチルシクロテトラシロキサンの導入をしゃ断し、酸素流量を５０ｓｃｃｍにし、同時に下部電極２に２５０ＫＨｚの低周波電源から２００Ｗの電力を６０秒間印加する。第１の実施例において詳述したように、この低周波によるイオンボンバートメントを有するプラズマ酸化によって、シリコーン系膜は緻密なシリコン酸化膜に変質する。以下、シリコーン系膜の形成とプラズマ酸化を交互に繰り返すことにより、第１の実施例と同様に、平滑な表面を有し、且つ緻密な膜質のシリコン酸化膜を任意の膜厚だけ形成する。

【００３０】本第２の実施例において有機シロキサンとしてオクタメチルシクロテトラシロキサンを用いたが、ヘキサメチルシクロトリシロキサン，デカメチルシクロペンタシロキサン，ヘキサメチルシロキサンまたはオクタメチルトリシロキサン等のメチルシロキサン類を用いても同様の効果が得られる。さらにエチルシロキサン類やフェニルシロキサン類を用いても良い。これらの有機シロキサン類にジクロルジメチルシランに代表されるハロゲン有機シランを混合すると重合が促進され、シリコーン系膜の成膜速度を高めることが可能となる。

【００３１】第３の実施例としては、第２の実施例において用いた酸素に代えて水蒸気を用いる。加速分解反応がプラズマ重合に加わるため、さらにシリコーン系膜の成膜速度が高まり、生産性を高めることができる。

【００３２】第４の実施例としては、第１の実施例において、シリコーン系膜を形成するに先立って、窒素ガスのプラズマに半導体基板１０をさらすものである。図６にシリコン酸化膜形成の各パラメータの時間変化を示す。シリコーン系膜を形成するに先立って、N_2 流量を１００ｓｃｃｍ，電源パワーを２００Ｗとして１０秒間さらす。この処理により図２（ａ）におけるシリコン酸化膜１１の表面が窒化され、疏水性化する。このため、シリコーン系膜（例えばジメチルシロキサン膜１３）のぬれ性が向上し、表面平滑性がさらに向上するという利点を生じる。窒素ガスの他、アンモニアガス或はそれらの混合ガスを用いても良い。

【００３３】

【発明の効果】以上説明したように本発明は、配線が形成された半導体基板上にシリコーン系膜を形成し、酸化性プラズマにさらす工程とを同一装置内で繰り返し、且つ、酸化性プラズマの励起電源に１ＭＨｚ以下の成分を含ませてシリコン酸化膜を形成することにより、平滑な表面を有し、緻密な膜質のシリコン酸化膜を形成することができる。この結果、次工程の熱処理工程でシリコン

酸化膜にクラックが発生することがなくなるため、上層の金属配線を形成してもコンタクト抵抗が増大することが無くなり、半導体装置の製造歩留り及び信頼性が大幅に向上するという大きな効果を有する。

【図面の簡単な説明】

【図１】本発明の実施例で用いられる装置の主要部分の構成図。

【図２】本発明の第１の実施例を説明するための半導体チップの断面図。

【図３】本発明の第１の実施例を説明するための各パラメータの時間に対する変化を示す図。

【図４】シリコン酸化膜の収縮率と低周波の周波数との関係を示す図。

【図５】本発明の第２の実施例を説明するための各パラメータの時間に対する変化を示す図。

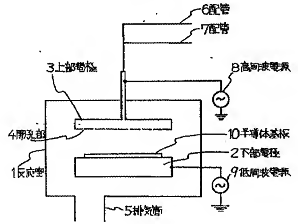
【図６】本発明の第３の実施例を説明するための各パラメータの時間に対する変化を示す図。

【図７】従来の半導体装置の一例を説明するための半導体チップの断面図。

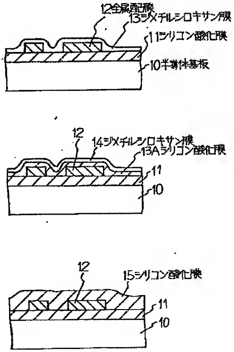
【符号の説明】

1　反応室
2　下部電極
3　上部電極
4　開孔部
5　排気管
6，7　配管
8　高周波電源
9　低周波電源
１０　半導体基板
１１　シリコン酸化膜
１２　金属配線
１３，１４　ジメチルシロキサン膜
１３A，１５　シリコン酸化膜
２０　シリコーン系膜
２１　シリコン酸化膜
２２　フォトレジスト膜
２３　コンタクト孔
２４　疎な膜質のシリコン酸化膜

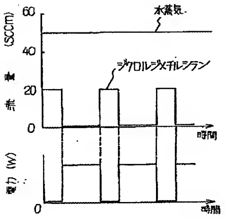
【図１】



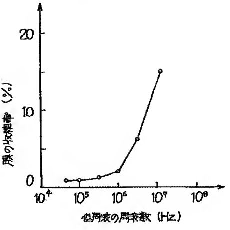
【図２】



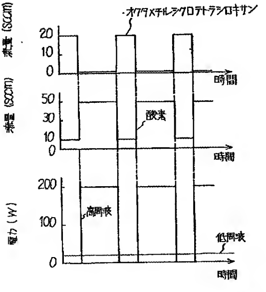
【図3】


60
40
20
0
流量 (SCCM)
水蒸気
ジクロルジメチルシラン
時間
電力 (W)
0
時間

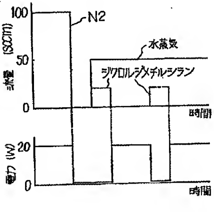
【図4】


20
10
0
膜の収縮率 (%)
10⁴
10⁵
10⁶
10⁷
10⁸
低周波の周波数 (Hz)

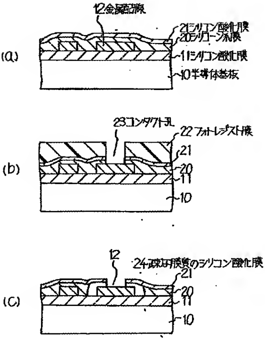
【図5】


オクタメチルシクロテトラシロキサン
流量 (SCCM)
20
10
0
時間
流量 (SCCM)
50
30
10
0
酸素
時間
電力 (W)
200
100
0
高周波
低周波
時間

【図6】


100
N2
50
0
流量 (SCCM)
水蒸気
ジクロルジメチルシラン
時間
電力 (W)
20
0
時間

【図7】


12金属配線
21シリコン酸化膜
20シリコーン系膜
11シリコン酸化膜
10半導体基板
(a)
23コンタクトホール
22フォトレジスト膜
21
20
11
10
(b)
12
24 疎な膜質のシリコン酸化膜
21
20
11
10
(c)